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THE INFLUENCE OF THE INTERFACE SHAPE ON THE PLANE-TO-CELLULAR-TO-DENDRITIC TRANSITION IN SUPERALLOY BASED OF NICKEL

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ABSTRACT

In this paper investigation of the influence of the crystallization conditions on the interface shape during the solidification of Ni-based Superalloy by Vertical Bridgman method were investigated. The samples were undertaken of the metallographic investigation of the microstructure. The critical rate of plane-to-cellular interface transition, R_{pc}, was defined and calculated.

Keywords: crystal growth, solidification, dendritic growth, interface shape, Ni-based superalloy

1. INTRODUCTION

The structure of single crystals of a superalloy based on nickel is dendritic, and the chemical composition is very inhomogeneous. If the content of the solute rises during solidilfication, the solid-liquid interface changes from planar to a cellular and finally to a dendritic one.

During directional solidification of alloys, the interface morphologies change from planar to cellular to dendrite as the velocity is increased. Extensive research has been done by several authors on the evolution of the S-L interface, both in dilute alloys and organic transparent alloys using the linear stability theory where the Constitutional Supercooling (CS) [1] is an important tool in order to predict solid-liquid (S-L) interface instabilities arising during controlled growth from the melt. For a given alloy the decreased of the parameter G_L/R, where G_L is the temperature gradient in liquid in front of the interface and R the solidification rate, controls the evolution of the S-L interface morphology. According to CS criterion, the planar interface becomes unstable above a critical growth rate, R_{PC} given approximately by:

$$\frac{G_L}{R_{PC}} = -\frac{m_L C_0 (1-k_0)}{k_0 D_L} \qquad (1)$$

where G_L is the temperature gradient in the liquid phase, R_{PC} the critical growth rate for beginning interface instabilit, C_0 the initial solute concentration, m_L the liquid line slope in the equilibrium diagram, k_0 the equilibrium coefficient of distribution, D_L the coefficient of diffusion in the liquid phase.

For the system with more solute components this criterion has to change into:

$$\frac{G_L}{R_{PC}} = \sum \{-\frac{C_0^i m^i}{D^i} \cdot \frac{1-k_0^i}{k_0^i}\} \qquad (2)$$

where C_0^i is the initial solute concetration from the i component, m^i the liquid line slope in the equilibrium diagram Ni-component i, k_0^i the equilibrium coefficient of distribution for the i component, D^i the coefficient of diffusion in the liquid phase for the i component.

2. EXPERIMENTAL

The experiments were performed using Bridgman method [2]. Temperature gradient in the furnace was measured and G is estimated to be 3350°C/m.

The materials used to grow the crystals of the superalloy had the following chemical composition (in mas.%): 8.6% Cr, 1.98% Ti, 5.1% Al, 11.1% W, 0.91% Nb, and 72.31% Ni.

The samples were longitudinally cut, polished, etched and then the metallographic investigation of the structure was performed.

3. RESULTS AND DISCUSSION

According to SC criterion, equation (2) was used to calculate R_{PC}, a critical growth rate when the planar interface becomes unstable. Values for m^i [3], k_0^i [4] and D^i [4] were taken from the literature (Table 1).

Near the critical rate, R_{PC}, the interface exhibited an irregular morphology. The unstable region lies between stable region for a planar interface (equation 1) and the stable region of regular cell. So the cellular interface was obtained at appreciable larger rates than R_{PC} [5]. On the other hand, the boundaries of these stable regions are not clearly distinguished. Although the critical rate for beginning of planar interface instability is defined, the precise moment of planar-to-cellular transition is not yet determined. What does the critical

microstructure looks like. and which is the critical rate for this moment? In our work it was assumed that the beginning of connection of cells represents the critical microstructure. This structure is obtained at remarkable higher rate than the calculated one.

Table 1 - The literature values for used Ni-based superalloy [4]

element	C_0 [mas.%]	k_0	m [°C/mas.%]	$D \cdot 10^5$ [m^2/s]
Ni	72.31	-	-	
W	11.10	1.5	-0.641	8.6
Cr	8.60	0.82	-1.180	5.0
Al	5.10	0.87	-15.44	19.0
Ti	1.98	0.73	-16.3	8.6
Nb	0.91	0.51		

On the based of our experimental data and values from the literature (Table 1), the critical growth rate for beginning interface instability, R_{PC} = 0.23 mm/min, was calculated, and cellular structure of samples are shown at Figures 1 and 2.

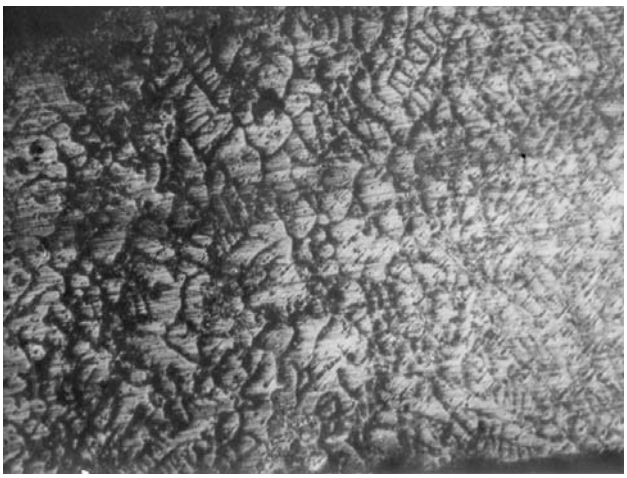

Fig. 1 - The cellular structure. Magification 24x

We are carefully investigated in our works on the system Al-Cu [6-8] the influence of the growth conditions to the interface shape and the critical growth of the rates R_{PC} were evaluated for the various Cu concentrations in the Al-Cu alloys.

It were performed investigations in the allows based Ni did the cell structrure of the seed influence to dendrite size, namely to primary dendritic spacing λ_1.

In our previous work [9] we concluded that the cell structrure of the seed did not influence to λ_1.

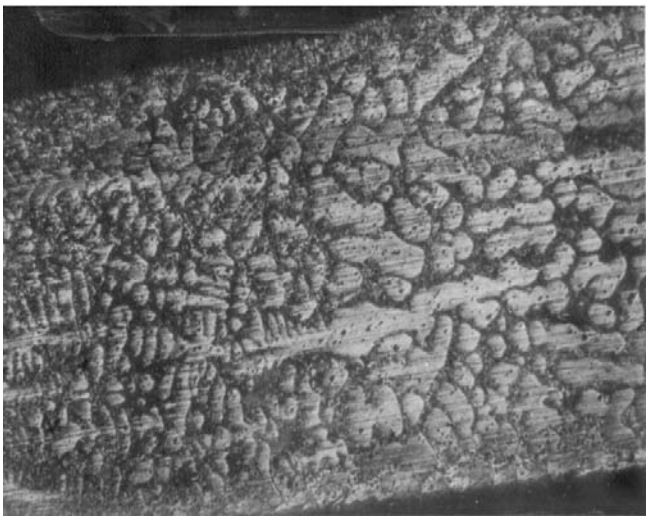

Fig. 2 - Transition from the cellular to dendritic structure. Magification 24x

Figure 3 shows a part of crystal which has only dendritic structure.

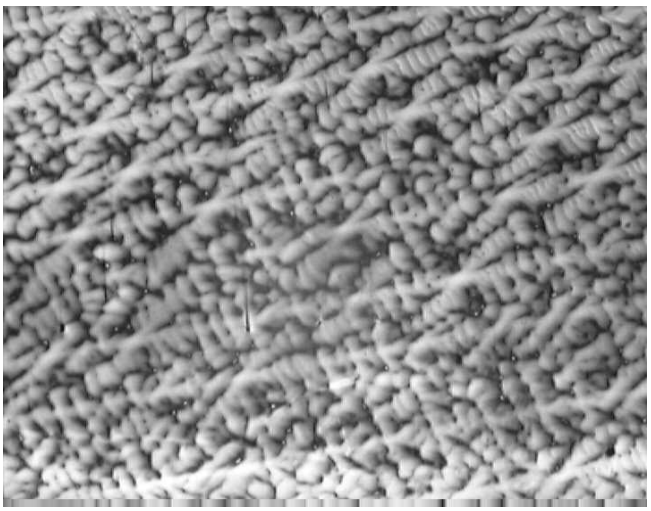

Fig. 3 - The dendritic structure. Magification 24x

Dendrite arm structure is an important consideration in cast superalloy based Ni microstructures. From the result of dendrite arm spacing, it is possible to obtain information on the influence of growth parameters (rate and temperature gradient) to a sample structure [10]. Dendrite arm spacing could be obtain using modern quantitative microstructure analysis (QUANTIMET 500 MC). This results will be presented in our next article.

4. CONCLUSION

The experiments were performed using Bridgman method.

On the based of our experimental data and values from the literature, the critical growth growth rate for beginning interface instability was calculated to be R_{PC}=0.23 mm/min.

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